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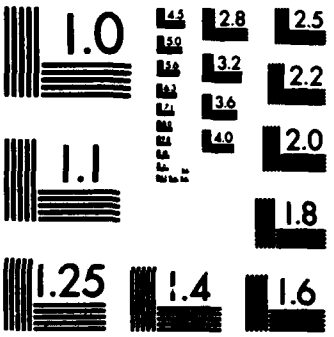

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FOREIGN TECHNOLOGY DIVISION

ANALYSIS OF THE DECOMPOSITION OF TRANSPARENT POLYMER MATERIALS (BLOCKS) UNDER THE ACTION OF LASER BEAMS IN FREE GENERATION MODE

by

M.A. Sultanov, B.N. Narzullayev, V. Urunov

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>
> Page 51.
>
> However, in recent years it has been shown that with the hereditary pigment degenerations in animals the biochemical changes are observed in all celluar elements of the retina.

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Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

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ANALYSIS OF THE DECOMPOSITION OF TRANSPARENT POLYMER MATERIALS (BLOCKS) UNDER THE ACTION OF LASER BEAMS IN FREE GENERATION MODE.

M. A. Sultanov, B. N. Narzullayev, V. Urunov.

(Presented by academician of AS of Tadzhik SSR O. V. Dobrovol'skiy 9 June 1969).

In the literature in essence was investigated mechanism of decomposition of transparent blocks depending on power of generation, on number of pulses/momenta, on focal length of lens and so forth on ruby and neodymium lasers both in regime/conditions of free generation and in regime/conditions of giant pulse/momentum. However, the mechanism of the decomposition of the materials indicated under the action of laser beams by the different authors is explained differently. For example, the authors of work [1] assume that the basic reason for the decomposition of transparent materials under the effect of laser radiation is the propagation of the acoustic waves, formed as a result of the forced combination scattering of Mandelstam-Brillouin - VKRMB. To the same opinion adhere the authors of works [2, 3], but in [4, 5] by the authors is proposed the mechanism of decomposition, which occurs due to the local heating of substance in the focus of ray/beam and formation of the foci of the high temperature, in consequence of which appear the dynamic stresses, which will lead to the shift effects. In [4] was also indicated the formation of the gas pockets in the material and of cracks in the form

cont'd pg.

of the "plates", arranged/located at an angle of 45° with respect to the direction of laser beam [6]. However, in [7] it is noted that crack formation in PMMA [ПММА - polymethyl methacrylate] is the result of the propagation of cross and longitudinal hypersonic waves.

From examination of literature data it is evident that unity of opinion to mechanism of decomposition of transparent materials (blocks) under effect of coherent emission at the present time still is absent. However, some experimental results, obtained by the authors of this work on the effect/action of supersonic plasma jets on different polymeric materials, showed that in the mechanism of decomposition the dominant role is played by thermal effects of [8]. Therefore it was of interest to check this assumption in the case of the effect of laser emission on the polymeric materials. For this purpose two laser installations on the glass with neodymium were assembled. Work was conducted in the regime/conditions of free generation. The sizes/dimensions of crystals comprised 12×120 and 12×140 mm respectively, time of generation - approximately 500 μs, the diameter of spot in the focus of ray/beam - on the order of 0.1 mm. Energy of generation on the installation was changed from 10 to 20 joules.

Were studied changes in form of fracture of blocks of polymethyl methacrylate - PMMA, quartz, glass, polystyrene in dependence on focal length of lens, power of generation of place of focusing of laser beam in material. The pictures of decomposition were investigated both

visually and photographically with the aid of the photographic camera and the microscope. (Russian Translations).

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The common picture of the decomposition of transparent materials (PMMA, polystyrene) under the effect/action of laser beams in the regime/conditions of free generation appears as follows.

With focusing of laser beam in PMMA, polystyrene materials are subjected to intensive decomposition, moreover decomposition is accompanied by formation of flat/plane, elongated cracks in the form of "plates" of different sizes/dimensions, arranged/located at different angles of inclination/slope relative to axis of light ray. In this case the cracks are asymmetrically displaced to the different sides from the axis of ray/beam and, as a rule, are strongly charred (especially in the polystyrene).

1. Investigation of picture of decomposition of transparent materials in dependence on focal length of lens. For this were used the lens with focal length of 33.75 and 150 mm.

Analysis of pictures of decomposition with this experimental variant shows that with increase in focal length of lens overall length of damage/defeat by light ray is increased. In this case the sizes/dimensions of cracks decrease along the diameter; however, their number is increased per unit of the length of ray/beam. A change in

the focal length affects also the angle of the slope of "plates" with respect to the axis of ray/beam. With an increase in the focal length the angle of the slope of cracks decreases.

Analysis of one of pictures of decomposition of PMMA under effect/action of laser beam with focal length of lens, equal to 150 mm, and energy of output/yield, equal to 10 joules, shows following.

Overall length of decomposition on light ray comprises more than 30 mm. In the work entire picture of decomposition was divided in three sections (on one centimeter) and was calculated a quantity of cracks for each of them. In this case it was explained that a number of cracks at a distance of 10 mm from the place of focus on the course of ray composes 100-110, the maximum/overall diameter of crack in this case having sizes/dimensions to 5 mm, minimum - 0.005 mm. In the following section a number of cracks composes 160-170; maximum/overall diameter - to 3 mm, minimum - 0.004 mm. In the latter/last section a number of cracks - 90—100; maximum/overall diameter - to 2 mm, minimum - 0.004 mm.

As can be seen from analysis of this picture, with removal of ray/beam from place of focusing, dimensions of cracks decrease. The greatest number of cracks falls in the middle section of the region of decomposition.

2. Study of form of fracture of PMMA and glass depending on

place of focusing. Laser beam with the aid of the lens with a focal length of 33 mm was focused on the front surface, in the volume and on the rear surface of material. Experimental results are shown:

a) with the focusing of ray/beam on the front surface is observed the formation of large "plates" in the focus (PMMA), and also chipping of material (glass), as a result of which occurs cratering, whose size/dimension depends on the power of generation and focal length of lens;

b) with the focusing of ray/beam within the material decomposition is observed both to the place of beam convergence and after it. However, to the place of beam convergence a number of cracks is less than after the focus. In the place of focusing is observed the presence of many cracks, situated also at different angles both with respect to the axis of ray/beam, and according to the relation the friend and the friend;

c) with focusing of ray/beam nearer to back edge of sample is formed one large "plate", then the formation of other cracks both in the beam direction and it is perpendicular to it, i.e., the part of the ray/beam changes its direction with respect to the original at angle of 90°.

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With the low values of energy of the ray/beam (less than 10 joules) it appears the additional decomposition, caused by the reflection of laser beam from the separate cracks, whose axes are directed approximately at different angles relative to the axis of the main

trend of laser beam. In this case the sizes/dimensions of cracks in the diameter it does not exceed 1.5-2 mm; they, as a rule, are oriented at angle of 45° relative to the axis of light beam and their quantity is changed depending on the power of generation.

But if we focus ray/beam very close to back edge, then chipping of surface (PMMA, glass) occurs, as a result of which cratering also is observed.

3. Study of pictures of decomposition in dependence on power. Experimental experiments show that with an increase in the power form of fracture is changed. Are increased the sizes/dimensions of "plates" in the diameter, an angle of the slope with respect to the axis of laser beam and a quantity of cracks (both large and small sizes/dimensions) in the unit of length in the light direction. In this case the microcracks are arranged/located by sizes/dimensions to 0.005 mm, formed as a result of decomposition, not only on the axis of ray/beam, but it is also scattered along the sides at different distance from it.

Fig. 1 gives photographs of decomposition of PMMA under effect/action of laser beam with two power coefficients. Focusing was produced within the sample by lens with a focal length of 33 mm. In the photographs horizontal arrow/pointer indicates the direction of laser beam for the given pictures of decomposition, vertical - places of focusing.

Analysis of experimental results shows that with energy of output/yield of generation in 10 joules (Fig. 1a) maximum/overall diameter of crack composes 2.1 mm and angles of slope of cracks with respect to axis of ray/beam it does not exceed 45°. But in the case, when energies of generation are approximately 20 joules (Fig. 1b), the sizes/dimensions of cracks reach 4.1 mm and more. In both cases the minimal sizes of cracks comprise to 0.2 mm. In this case the inclination/slope of cracks to the axis of laser beam can exceed 45°. This is especially well noticeable at the power of generation of approximately 20 joules. From the comparison of photographs (a) and (b) it is possible to easily note a difference in form of fracture not only in dimensions of cracks, but also in their quantity throughout the entire length of laser beam and on the inclination/slope of some cracks.

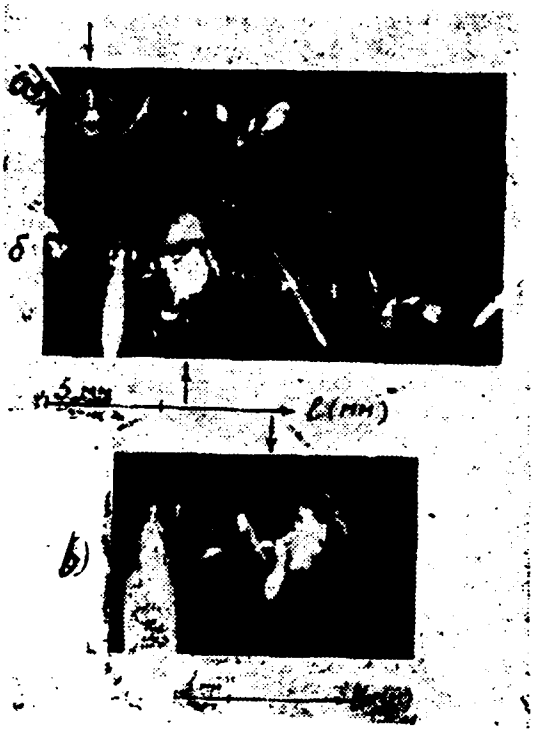

Fig. 1. Pictures of decomposition of PMMA under effect/action of focused laser beam: a) at power of generation 10 joules. magnification 8×; b) at the power of generation 20 joules, mag. 8×; c) the enlarged image of the place of the focusing of ray/beam, mag. 16×.

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Greatest decomposition is observed in places of focusing of laser beam. Here all cracks are strongly charred. Even during the more powerful regimes/conditions of generation (about 20 joules) in the material in the place of focusing it is possible to observe the charred cavities (volumes). For the example in Fig. 1c is given the photograph of decomposition of PMMA in the place of focusing (the enlarged image Fig. 1b). From the photograph one can see well that in

the place of the focusing of ray/beam is a greatest decomposition. Furthermore, the presence of many cracks of different diameter, arranged/located at different angles to the axis of ray/beam, is evident.

Experimental results, obtained in this work, aim authors on thought, that during more powerful/thicker regimes/conditions of generation in initial stage of reaction of laser emission with transparent materials it is not possible to explain crack formation by effect VKRMB, since with this effect, according to literature data, must be formed "plates" with inclination/slope toward axis of ray/beam at angle approximately in 45°.

Mechanism of decomposition of transparent materials under action of beams of lasers during powerful mode of generation to us is similar.

With passage of laser beam through transparent materials in places of focusing material rapidly is heated and changes into liquid state, in which occurs further energy absorption [9]. As a result is formed the plasma, which is expanded at a high speed. Phenomenon is reduced to the point, instantaneous and powerful/thick explosion. This process carries hydrodynamic character and is accompanied by the formation of shock wave. In this case it is propagated at hypersonic speed, which leads to additional decomposition of sample both up to the focus of laser beam and after it.

Presence of intensive burning of material and formation of numerous cracks at different angles up to 80—85° with respect to axis of light beam can serve as confirmation of fact that in place of focusing plasma, is formed. However, after the focus of ray/beam crack formation, obviously, occurs due to the propagation of the hypersonic waves, formed during the explosion, and therefore cracks with the inclination/slope of more than than 45° are not observed.

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